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John A. Widtsoe

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EXPERIMENT STATION.

OF

THE AGRICULTURAL COLLEGE

OF UTAH.

Bulletin No. 52.

THE CHEMICAL COMPOSITION OF UTAH SOILS.

CACHE AND SANPETE COUNTIES.

JANUARY, 1898.

LOGAN, UTAH.

Press of THE UTAH LITHOGRAPHING CO.
Salt Lake City

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The Chemical Composition of Utah Soils.

CACHE AND SANPETE COUNTIES

BULLETIN No. 52.

BY JOHN A. WIDTSOE.*

CONTENTS.

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*The analytical work recorded in the following pages has been done by John A. Widtsoe, W. W. McLaughlin, John M. McFarlane, John Stewart and J. C. Thomas. All the soil samples were collected by John A. Widtsoe, and all the work has been done under his direction.

A—INTRODUCTION.

1. THE APOLOGY.

The officers of the Utah Experiment Station realize that, in order to serve the agricultural interests of Utah in the best manner, they must be in possession of extensive information concerning the soils and the climate of the State. The climate of a district, similar to that which includes Utah, is quite easily learned, and, as observations extending over many years have been made, a fairly complete understanding of the climatic conditions of Utah has already been obtained.* The soils of the State, on the other hand, have not, as yet, been subjected to any systematic study; in reality, nothing of importance is known of them, beyond the fact that, wherever water enough can be obtained, they have been uniformly productive.

The soils of the State, as found by the Mormon pioneers of 1847, were virgin in the fullest sense of the word. As far as man knows, only a few patches in Southern Utah had ever been cultivated. For untold centuries the atmospheric forces, unhindered by man's intervention, had been allowed to weather and make fit for agricultural purposes the rock fragments that, washed down into the valleys from the mountain ranges, constitute the soils of the State. For a long period, also, long before human tradition begins, there had not been enough water in the Utah valleys to drain through and cause a loss of soluble plant food. In every way, then, the early and present conditions of the land have combined to produce soils of exceptionally great fertility. The only element of plant food that may have diminished under the prevailing conditions, can easily be added to the soil by the application of recent discoveries in agricultural science.

In spite of the great fertility of Utah soils, as shown by the geological history of the district and by the yields of crops that have been obtained, complaints are now and then received from different parts of the state, that soils which formerly yielded well are decreasing in productive power. As a rule, such degeneration can be referred back to improper methods of tillage, rather than to the exhaustion of plant food, but, in a few cases, it is quite impossible to explain without a very close and comprehensive study, the cause of the change.

*See The Climate of Utah, by James Dryden. Bulletin 47 of the Utah Experiment Station.

As the State grows older and the soils are tilled longer, there is no doubt that such complaints will become more frequent. To meet them, and to be able to suggest remedies, the station must have at hand a stock of facts relative to the nature of Utah soils. Moreover, a better knowledge of the soil conditions of the State may enable the station to suggest changes in cultivation that will lead to more profitable results than the partially successful methods now in vogue. The study of the soils of a district is unquestionably of the highest value to the best farm practice.

THE WORK ATTEMPTED.

The first step in the study of a series of soils is to compare them with soils of known quality and composition, in order to form a *general* acquaintance with them. Following this general study is the detailed examination, which brings out individual characteristics that would be overlooked in the general work. Nearly all soils that have been examined up to the present have been considered with reference to the amount of plant food which they possess. We have, consequently, many thousand chemical analyses of soils taken from all parts of the world. The study recorded in this bulletin refers to the chemical composition of the soils taken up; and aims to bring out any marked difference that may exist between Utah soils and those of other regions.

This work is only preliminary to the more extensive study of soils taken up by the Station. As time will permit, investigations relative to a better method of valuing a soil for agricultural purposes will be carried on, and applied as early as possible to the soils of this State. Such work requires much time, much money and much interest on the part of those in charge of the Station work. It is the hope of the writer, that for a long time to come, knowledge concerning the nature of the soils of Utah for the purposes of maintaining and bettering agriculture, will be eagerly sought by the officers of the Utah Station.

2. THE METHOD OF SOIL COLLECTION.

To study the soils of a state, especially of a large state, by taking a sample here, and a sample there, over the whole extent of the state, will not generally furnish valuable results. A small district should be chosen that represents some geographical or geological division, and a great many samples taken from that one district. Only in this way can the accidental or local variations be eliminated, and the general properties of the soils of the whole district be established. Taking, then, the whole state, district by district, an accurate understanding of all the soils will be obtained, and the boundaries of each soil variety clearly defined. This method involves, of course, much labor, but its results are more certain, and consequently of greater value, than the results of a survey based upon a small number of samples.

In the work recorded in the following pages, an attempt has been made to follow this method. Utah offers especial advantages for division into districts, as nearly all the agricultural lands of the State are situated in valleys. Some of these valleys are not much more than coves, capable of supporting four or five families each; others are more like large plains, similar to the prairies, in which twenty or thirty villages may be found. As far as the work has progressed, each valley has been studied in detail. The person instructed to collect the soil samples has gone over the valley in every direction until thoroughly familiar with its appearance; then the samples have been taken from all parts of the valley. A soil analysis is a long and laborious task. The assistance in the laboratory was until recently vanishingly small, and all the samples collected from the valleys visited could not therefore be analyzed. The results are, however, as complete as the circumstances would allow.

Soil samples were first taken from Cache and Sanpete counties, which are the chief wheat-producing districts of Utah. The amount of chemical analysis decided upon for these counties has been finished; and the results obtained are presented herewith. Other counties have been visited and samples collected, and as time permits they will be studied.

B—THE RELATION OF THE PLANT TO THE SOIL.

3. THE ASH OF PLANTS.

HOW A PLANT FEEDS.

A plant, like an animal, requires food in order that it may live and prosper. Plants take their food from the air and from the soil. From the air they take the carbon, which constitutes about one-half of their dry substance; from the soil they take water, nitrogen and all mineral matters. The feeding from the air takes place by means of the leaves; from the soil, through the action of the roots.

When a plant is burned at a low temperature, all the water and most of the carbon and nitrogen contained in the plant escape as smoke or invisible gases, and only the mineral matters, or ash, remain. The ashes of all plants are alike in that they consist of a number of distinct substances; they are unlike in the proportions in which these ingredients occur.

The important substances that are found, almost without exception, in all plant ashes are: *Potash*, *Soda*, *Magnesia*, *Lime*, *Iron Oxide*, *Alumina*, *Manganese Oxide*, *Sulphuric Acid*, *Phosphoric Acid*, *Carbonic Acid and Silica*.

ESSENTIAL ASH INGREDIENTS.

As all plant ashes are composed of the same substances, the question early arose if a soil which did not contain all these substances could support plant growth through all its stages. To answer this question, hundreds of experiments with artificial soils or with nutritive solutions were made. One favorite manner of attacking the problem was to add to a jar of distilled water all the substances found in plant ashes except potash, and to another all except phosphoric acid, and to a third all except iron, and so on with all the ash ingredients. Seeds were then allowed to germinate and grow in these solutions. If the plant in the jar that contained no potash died before maturing, it was taken as an evidence that potash is essential to the growth of the plant; if the plant in the jar that contained no aluminum grew normally and produced seed, it was taken to mean that a plant can live without aluminum. Another method was to use, instead of distilled water, pure quartz sand, containing all but a certain one of the ash ingredients, and to grow in it certain plants. Whenever a pot carried a plant that did not develop properly, the substance wanting in that jar was said to be essential to the life of the plant. The concordant results of many such experiments have led to a knowledge of the substances which a plant *must* receive in its food, if it shall grow and bear fruit, and which a soil must possess if it shall be used for the growing of crops.

The ash ingredients absolutely indispensable to plant growth are: 1, Potash; 2, Lime; 3, Magnesia; 4, Oxide of Iron; 5, Sulphuric Acid; 6, Phosphoric Acid; 7, Nitric Acid and 8, Carbonic Acid.*

*The Carbonic Acid is not a constituent of pure ash. It is taken fromt the air by means of plant leaves.

UNESSENTIAL ASH INGREDIENTS.

If these eight substances are the only ones that a plant must have for its well being, why is it that we find so many unessential ingredients in plant ashes. This can be made clear by referring briefly to the manner in which a plant takes food from the soil, and to the general composition of soils.

Plant roots end in very small hair-like bodies, known as root hairs, which are hollow cylinders filled with an acid juice. The roots, foraging for food, come into contact with the particles that make up the soil. If the particles are surrounded with water, holding in solution plant food, this passes directly into the interior of the root hair and is then forced upward, through the root and the stem, to the parts of the plant that are in need of nourishment. If, however, the water in the soil is deficient or does not hold in solution the necessary food, the roots must dissolve from the soil particles whatever they need. The roots are brought into direct contact with the soil grains, which are then acted upon by the acid juices of the roots and root hairs and partly dissolved; and the dissolved material is brought into the system of the plant. As plants lack any marked power of selecting the useful and rejecting the useless, whatever is dissolved from the rock fragment is taken into the root regardless of its value to the plant. Further, since all soils contain many substances that are not necessary to the life of plants, but are as readily soluble as the true plant foods, it is easily understood that plants will take up many bodies of little or no value to the life processes and which will be found in the ashes of the burned plant.

4. WHAT MAKES A SOIL FERTILE?

THE VALUE OF CHEMICAL ANALYSIS.

If certain substances are indispensable to the growth of a plant, will not the fertility of a soil be established when the chemist shows that it contains them all? The answer given to the question, when it was first asked, was a decided, yes; today it is a decided, no.

The essential elements of plant growth must not only be *present;* they must occur in a certain abundance, and in such a condition that they are available for plants. A soil may contain potash, yet not enough, in the volume reached by the roots, to support the plants; or, a soil may be rich in potash which is locked up so firmly in insoluble compounds that the plant juices have no power to dissolve it. The chemist, then, in estimating the value of a soil, tries to imitate the action of the plant roots, and acts upon the soil with acids that have as nearly as possible the strength of the juices in the plant roots, and determines how much of each essential plant food is dissolved. Nearly all American soil analyses have been made by acting on the fine portion of the soil (the part that goes through a half millimeter sieve) with hydrochloric acid of the specific gravity 1.115. This strength of acid was chosen for convenience, and it is unfortunate that it appears to be stronger in its action on soils than the plant roots. All analyses made with this solvent will, therefore, show more available plant food than actually exists in the soil. However, so many analyses have been made with this solvent, on soils of known fertility, that an analysis made by this method shows with considerable certainty the state of the soil as regards its fertility and its particular weaknesses. In the present state of the study of soils this method is undoubtedly the best one to follow.

FERTILITY NOT DETERMINED BY PLANT FOOD ONLY.

Of very great importance is the physical condition of the soil; the sizes of the grains that constitute it; the proportion of each group; their arrangement, etc. A soil very rich in plant food, but in a poor mechanical condition, would be of less value to the growing crop than a soil with a smaller amount of plant food but in excellent tilth. The farmer has the physical state of the soil under his partial control, through the application of simple and well known principles of tillage; but must take the general composition of the soil as it is; the latter, therefore, becomes of greater importance than the former. Given the same physical structure of a number of soils, and the same climatic conditions, the one having the greatest amount of available plant food, below a given limit, will yield the fairest crops. Given the same chemical composition and the same climatic conditions, the soil with the best physical structure will yield the best results. Soil physics has not yet the same firm foundation that soil chemistry possesses; and its results are not, therefore, at the present, of the same value. In time, the methods of the chemical and physical examination of soils will be bettered and made definite. Then it will be possible to estimate from the results of laboratory tests the agricultural value of a soil. At the present, the judgment that can be passed upon a soil from a set of analytical results is very unreliable indeed.

5. AMOUNT OF PLANT FOOD IN FERTILE SOILS.

From the analysis of a great number of soils, the agricultural values of which were approximately known, Professor Hilgard of the University of California, who is the American authority on soils, has formulated a set of statements which may be used in the interpretation of the analytical results of soils. Extracts from these rules, as found in the Report for 1888 and 1889 are as follows:

POTASH.—"No virgin soil having 0.50 per cent or over of potash will wear out first on that side of its store of mineral plant food; and much less will suffice in the presence of much lime and humus."

LIME.—"The amount of lime required to render a soil practically a calcareous one varies greatly according to the nature of the soil. A broad statement may, however, be made to the effect that that amount is very much greater in clayey than in sandy ones, and may be said to vary directly as the amount of clay in the soil." The amount seems to vary from 0.12 per cent in sandy soils to 0.50 per cent in clayey ones. "I have not seen any advantages to accrue to a soil from an increase of lime beyond 1.5 to 2.0 per cent, except that heavy, clay soils are somewhat lightened by granular carbonate."

PHOSPHORIC ACID.—About 0.10 per cent seems to be a sufficient amount of phosphoric acid. In the presence of lime a smaller quantity may suffice.

6.—THE COMPOSITION OF SOILS AND DEFINITION OF TERMS USED.

Soils wherever found contain, with a few exceptions, the same ingredients in varying proportions. The substances sought for in an ordinary analysis are the following:

1. Insoluble Residue, 2. Potash, 3. Soda, 4. Lime, 5. Magnesia, 6. Oxide of Manganese, 7. Oxide of Iron, 8. Alumina 9. Phosphorus Pentoxide, 10. Carbon Dioxide, 11. Organic Matter, 12. Humus, 13. Nitrogen, 14. Water.

Of these substances, water, potash, soda, lime, magnesia and oxide of iron are familiar to all.

INSOLUBLE RESIDUE is that portion of the soil which remains after the acid digestion.

OXIDE OF MANGANESE is a black or brown solid of no especial importance.

ALUMINA is the oxide of the metal aluminum. All clays, and nearly all igneous rocks contain alumina. Roughly, it may be said to be a measure of the amount of clay contained by soils.

PHOSPHORIC PENTOXIDE is a white, feathery solid that unites with water to form phosphoric acid. In soils it is always present in combination with the metallic oxides.

ORGANIC MATTER represents the combustible portion of soils.

HUMUS is a black or brown body formed by the decomposition of vegetable matter in the soil. It is rich in nitrogen, and contains much easily available plant food. It is a valuable soil constituent.

NITROGEN in soil is mainly combined with humus and organic matter, from which it may be set free in a form suitable for the use of plants.

7—METHODS OF SAMPLING AND ANALYSIS.

The soil samples to be discussed in the following pages were all taken with a 2-inch wood auger. Top soils were taken to a depth of twelve inches; and subsoils from twelve to eighteen inches.

The samples were prepared for analysis, and analyzed, according to the methods prescribed by Professor E. W. Hilgard and the association of official agricultural chemists. In a few cases only were the methods varied for the sake of convenience.

The method of digestion was to place about 10 grams of the soil with 100 cc of hydrochloric acid of Sp. Gr. 1.115 in an Erlenmeyer flask, closed with a long glass tube, which acted as a return condensor. The charged apparatus was heated on the steam bath for twelve hours.

C—THE SOILS OF CACHE COUNTY.

8—DESCRIPTION OF THE VALLEY.

LOCATION AND FORM.

Cache Valley lies in the northern part of the State, and crosses the boundary into Idaho. In shape it is a large irregular oval, with the long axis lying north and south; about forty-five miles long and fifteen miles wide. On all sides it is surrounded by high, deeply furrowed mountains that are spurs of the

Wasatch range. The mountains on the east are higher and more extensive than those that form the western boundary, and which are a divide between Cache Valley and the Valley of the Great Salt Lake with one of its tributary valleys. The floor of the valley is a broad, faintly undulating plain, which merges gradually with the gently inclining foothills that cover the bases of the mountains. In the south end, and near the middle of the east side, the gentle inclines of the foothills are marred by large, irregular or fanshaped, flattopped hills that are thrown back against the canyon mouths.

RIVERS.

Rivers come into the valley from the north, the east and the south. Bear River enters the valley from the north; from the mountains on the east and near their middle, comes Logan River; from the eastern mountains, but near the southern end of the valley, comes Blacksmith Fork River; and from the south, Little Bear River. Numerous smaller streams, which issue chiefly from the eastern mountains, are taken up by the rivers. Bear River flows southward, near the middle of the valley, until almost half way down, when it turns to the west and escapes by a narrow gorge, the Bear River Narrows, into the valley of the Great Salt Lake. The other large rivers unite in the south, central and southeastern parts of the valley, and flowing north, finally unite with Bear River, just after it has turned west. All the drainage of the valley occurs, therefore, through one pass.*

INHABITANTS AND CROPS.

The inhabitants of Cache County (which includes the lower three-fourths of Cache Valley), number about 20,000, and are composed mainly of industrious and intelligent Mormon settlers. The people live in villages that are surrounded by the farms. The staple crops are wheat, lucern and potatoes.† The number of acres under cultivation in 1895 was 73,057. The amount of cultivated land is naturally limited by the water supply; and as ditches, dams and reservoirs are built, the acreage will increase. The yield of crops in Cache

*For a full discussion of The Water Supply of Cache County, see Bulletin No. 50, by Samuel Fortier.

†The yields in 1894 were as follows: Wheat, 830,787 bu.; lucerne, 39,838 tons; potatoes, 207,300 bu.

Valley is exceptionally high when sufficient water can be obtained—so high, indeed, as to give to the valley the popular name of the Granary of Utah.

9. THE EARLY HISTORY OF THE VALLEY.

THE CIRCULATION OF WATER.

To understand the meaning of the analyses of Cache Valley soils it is of value to know, in a general way, the early history of the valley and the region to which it belongs. This must be prefaced with some general statements of the nature of the circulation of water.

The rays of the sun beat down upon the surface of the ocean and their heat energy is converted into a means for evaporating water. The water vapor rises from the ocean into the air, and there collects into clouds which, set in motion by air currents, are often driven from the ocean to the land and into the interior of continents. There they come into contact with the large mountain ranges and peaks, and the water vapor in them is precipitated as rain or snow. The rain or melted snow running down the mountain sides, collects into rivulets, they into creeks and they in turn into large rivers. The rivers carry the water down lower and lower and finally deposit it in the ocean. There the energy of the sun again changes it into vapor, and the same process is repeated. Thus, year after year and century after century, water goes through the phases of its circulation: ocean water, water vapor, clouds, snow or rain, river water and ocean water again.

In its descent from the mountains to the lowlands, water acts as a scouring and levelling agent, and brings down into the valleys the material found among the hills and mountains. Water, in its circulation, is, in fact, one of the most active agents in modifying the earth's surface.

WHAT ARE DRAINAGE BASINS?

The area of country that furnishes water to a river is said to belong to the drainage district or basin of that river. Take, for instance, the Mississippi. All the country that carries tributaries to this great river constitutes the basin of the Mississippi. Now, nearly all rivers empty into the ocean and consequently nearly all basins are open or drain into the sea. In the interior of large continents, under peculiar climatic conditions, there may be rivers that never reach the sea. They may run for hundreds of miles and grow larger and larger by the addition of water from numerous tributaries, but finally empty into some valley, where a lake will be formed, from the surface of which evaporation will begin. If more water evaporates from the surface of this lake than its tributary rivers bring to it (and this is very possible in dry climates) it will grow smaller and smaller, until the evaporation from the surface just equals the water brought in. If less water evaporates from the surface than the rivers contribute, the lake will grow larger and larger until the low places are filled with water and some place is found, in the rim of the basin, where the water can run over and find its passage to the ocean. The waters in the basin would then constitute an ordinary lake. In the former case, the evaporation was less than, or just equal to the water supply; and all the country furnishing water to this lake without an outlet, the drainage basin of the lake, would be called *a closed basin*, to distinguish it from one that communicates with the ocean.

LAKE BONNEVILLE.

Several such closed basins are found upon the American continent. One of the most interesting is that which includes the Great Salt Lake. This dead sea of the West is fed by many rivers of considerable size, but the climate is so dry that as much water evaporates from its surface as is brought to it by the rivers. If by any means the evaporation could be diminished, or the rainfall increased, the lake would increase in size; and, if the relative rainfall continued unchanged, would fill all the low places, and at last find a depression, the lowest point on the rim of its basin, for its outflow.

This was the exact condition of the Great Salt Lake many ages ago. The climate then was different from the present climate; the rainfall was relatively greater than at present; and the valleys that contain the rivers that feed the Great Salt Lake were filled with water. Not only these valleys were filled, but also the basin of the Sevier River, and the Escalante Valley, and others, which adjoined the Salt Lake basin, and were separated from it by lower rims than those which separated them from the ocean. The large prehistoric lake, the waters of which filled the western valleys of Utah, has been called Lake Bonneville.

CACHE BAY OF LAKE BONNEVILLE.

The only part of this ancient lake that comes under the present discussion is Cache Valley, which, during the period of Lake Bonneville, formed a bay that was connected with the main body by the "Narrows," through which Bear river now flows. The valley, at its north end, contained the outlet of the lake, over the Red Rock Pass, north of Franklin, and bore, therefore, important relations to the lake as a whole. Everything about the valley was at that time very much as it is to-day, except that it was filled with water which stood, at the time of its greatest height, 500 feet above the level of the Logan Temple.

EVIDENCES OF SUBMERSION.

There are plenty of evidences that Cache Valley was at one time filled with water. Standing on any piece of elevated ground, the beach marks may be traced for miles along the sides of the mountains. Other facts about to be mentioned bring out the same idea even more convincingly.

What first strikes the visitor to Cache Valley is the marked contrast between that part of the mountains which was above the water level and the part that was under water. Above the water line the mountains are cut up into numberless furrows, separated by sharp ridges: all is angular. Below the water line all is rounded in outline; there is no sharp turn and no hollow, for all unevenness has been smoothed. There is no gradation from the one to the other: the distinct beach mark effects a sharp separation. Nowhere can the difference between subærial and subaqueous actions be found better illustrated than in Cache Valley. As one looks up the mountain sides and marks this contrast he feels as if he is on a sea bottom; as if the water is above his head, and he is looking upward, through the water, to the shore. That part of Cache Valley which is used by man is nothing more or less than an old lake bottom.

ANCIENT DELTAS.

At the mouths of the canyons where the rivers emptied into the quiet water of the bay there would be a sudden deposit of all the heavy stones carried down by the mountain torrents, and, as a result, the mouths of the canyons and the space in front of them would be filled. Such deposits at the mouths of rivers are called deltas. Some of the finest specimens of fossil deltas known are found in Cache Valley. In front of Logan Canyon there is a large and very symmetrical delta, on the upper terrace of which the State Agricultural College is built. Blacksmith Fork River built a large delta, on the edge of which the city of Hyrum is situated. Little Bear River and the neighboring streams also built deltas that almost fill the south end of the valley. The upper parts of these deltas would, naturally, be made up of coarse material of less value for agricultural purposes than the lower parts and the lowlands. This will be illustrated in the analytical section. The hills mentioned, a few pages back, as breaking the uniformity of the gently rising foothills are these deltas, which are also additional proofs of the former submersion of the valley.

10. SOURCES AND NATURE OF THE SOIL.

With the facts above outlined, a fairly clear understanding of the nature of Cache Valley soils may be obtained. In those early days, as now, the rivers flowed into the valley. As they came from the mountains, they carried heavy charges of sediment, that were deposited when they emptied into the comparatively quiet waters of Cache Bay. The heavier materials would sink near the shore, while the finer portions would be carried out into the middle of the lake and there sink.

The range of mountains that forms the eastern as well as the western boundary, is made up of massive beds of limestone and dolomite heavily charged with sand. The rocks that face the valley belong to the Silurian era; behind, and deeper in the mountains, are limestones from the carboniferous era, with occasional deposits of sandstone and shale of the same geological age. Bear River, coming from a different district, has a greater variety of rocks to draw upon for its sediment, and is, consequently, charged with fragments of crystalline rocks in addition to broken down limestones, shales and sandstones. From these materials the soils of Cache Valley were made; the soils would therefore be expected to be constant, or nearly so, in composition. As will be seen later on, this expectation has been realized.

DISTURBING INFLUENCE OF BEAR RIVER.

Bear River, in recent days, has, however, modified somewhat the soils along its course. As the old lake dried and the water receded, the rivers were compelled to cut channels for themselves in the former lake bottom. Bear River, while accomplishing this purpose for itself, hesitated considerably about the route to select, and meandered widely. As a result it stirred up the soils along its course and exerted a separating action upon them. In some places it would move slowly, depositing rich sediment. In other places large eddies were formed and sandbars, which are now often used as farming land, resulted. Along the course of Bear River, therefore, several types of soils are found, while elsewhere in the valley the difference in soils is small, if we except the upper delta soils. In a few places on the west side of the valley heavy clay soils, resulting from the disintegration of local rock deposits have been noticed.

With this preliminary discussion the analyses of Cache Valley soils can be taken up.

11.—SOILS FROM THE SOUTH END.

(Paradise and Hyrum.)

GENERAL.

The south end of Cache Valley is pretty much filled by the ancient deltas of Blacksmith Fork and Little Bear River and their tributaries. The towns of Paradise and Hyrum are, in fact, built on the edge of deltas. The rivers, when the waters of Lake Bonneville fell, sought new and lower channels and, in so doing, cut down through the delta deposits with the formation of bottom lands. The farming lands of this section are located partly on the delta, or "wash from the canyon," and partly in the river bottoms or "hollows." The analyses given in the table represent the chief kinds of soil found near Hyrum and Paradise. On the upper lands the soils are sandy loams, rich in plant food, and, considering their origin, surprisingly rich in humus. In various places are found deposits of a loam containing more clay, such as is represented by sample 2067; and which are claimed by some of the farmers to be the richest land, especially for wheat raising. The bottom lands, represented by 2079, contain more clay than the bench lands, and more organic matter, and, in general, more plant food; they are very fertile soils. The soils lying beyond the deltas, and not in the "hollows," are represented by 2061. In composition they stand midway between the bench lands and the river bottoms.

All kinds of soil lying in the southern end of the valley are rich in mineral plant food, and, consequently, fertile.

COMPOSITION OF SOILS FROM THE SOUTH END.

(Paradise and Hyrum.)

LABORATORY NUMBERS.	2067	2074	2162	2070	2079	2062	Avera e
Insoluble Residue	76.51	85.19	85.44	82.36	71.14	81.13	80.30
Potash (K_2O)	1.04	0.62	1.15	0.74	1.48	0.69	0.95
Soda (Na_2O)	0.99	0.27	0.67	0.62	0.66	0.29	0.59
Lime (CaO)	0.83	0.69	0.60	0.86	1.66	2.10	1.12
Magnesia (MgO)	0.50	0.55	0.49	0.67	2.42	0.56	0.87
Oxide of Manganese (Mn_3O_4)	0.00	0.07	0.02	0.00	0.00	0.00	0.02
Oxide of Iron (Fe_2O_3)	3.94	2.84	2.83	3.14	3.92	2.38	3.18
Alumina (Al_2O_3)	8.30	4.37	4.28	4.88	8.20	4.70	5.79
Phosphoric Acid (P_2O_5)	0.18	0.18	.....	0.24	0.39	0.24	0.25
Carbon Dioxide (CO_2)	.....	.....	....	.....	.....	.....	....
Organic Matter	7.49	5.63	4.97	6.68	10.30	7.78	7.14
Total	99.78	100.15	.....	100.19	100.17	99.87	100.03
Humus	2.55	2.61	2.24	2.96	4.34	3.38	3.01
Nitrogen	0.120	....	....	.....	.....	.....	.....
Water at 15° C	3.07	1.48	1.52	1.67	3.46	2.06	2.21

NOTES.

2067—From the farm of James Lofthouse, in Paradise, is said by him to represent the best farming land in the district. Brown, medium loam; depth 0-12 inches, cultivated 12 years, but never manured. It has a high per cent of potash, but its content of phosphoric acid is somewhat below that for Cache Valley soils.

2074—A dark brown, sandy loam, which is black and plastic when wet, from the farm of James Lofthouse, at Paradise. Classed as the poorest land of the district, though with proper treatment it yields fair crops. Differs from 2067, which represents the first grade, in being more sandy and in carrying a little less potash and lime. The chief difference is in the organic matter of which it contains but two-thirds as much as 2067.

2162—Subsoil to the above (2074). Taken to a depth of 12-18 inches. Slightly darker than the top soil but agrees with it fairly well in chemical composition, except that it is richer in potash and poorer in organic matter.

2070—Along the road from Paradise to Hyrum, on the ancient delta of the Little Bear River, are many fertile farms, and there would be more with larger water canals. Four miles north of Paradise, on the bench, sample 2070 was taken to a depth of twelve inches. It is representative of the majority of soils between Paradise and Hyrum. In color it is brown, tinged with gray. In composition it is a sandy soil, rich in potash, lime and humus.

2079—Paradise Hollow, which contains much good farming land is the channel of the Little Bear River and extends from the mountains, by Paradise, to Hyrum. This sample was taken from Paradise Hollow, just south of Hyrum. Depth 0-12 inches. Cultivated. Dark gray, soft to the touch, and carries a considerable proportion of clay. Rich in potash, lime, phosphoric acid, organic matter, and humus, and is altogether a rich soil, quite typical of the river bottoms of this valley.

2062—Hyrum is built on the edge of the delta of the Blacksmith Fork River, and much of its farming land lies under the hill, and stretches away towards the middle of the valley. This sample, taken about one-half mile north of Hyrum, represents the cultivated soils of this district. Depth 0-12 inches. Virgin. Black brown in color; sandy to the touch. Rich in all essential plant foods.

12. SOILS FROM THE WEST SIDE, SOUTHERN HALF.

(Wellsville, Mendon, Petersborough and Cache Junction).

GENERAL.

Going west from Hyrum, the first town is Wellsville. From Wellsville the whole western side was skirted, touching in one trip, Wellsville, Mendon, Petersborough and Cache Junction. Around Wellsville, towards Mendon, the soils are sandy loams that increase in clay as Mendon is approached. Samples 2058 and 2085 represent the majority of these soils. They are rich in plant food, and contain more lime than the average of Cache Valley soils. Not far south of Mendon a marked change occurs in the soils; they become heavier or richer in clay, and continue to remain so until Cache Junction is reached. Nos. 2071 and 2073 represent the soils with a higher clay content, found around Mendon. Just west of this town is a large area of what looks like a very black, stiff clay. Patches of the same material are found in moving upwards to the foothills, and No. 2163 is a representative sample of the variety. Judged by the standards in our possession, these soils are all that can be desired; and the cultural results have for years proved their fertility. At Cache Junction, representing the extreme north of the section included under this heading, samples 2160 and 2166 were taken, and their analyses show them to be loams, richer in clay than the samples just discussed. The soils from

Wellsville to Cache Junction are very uniform, differing only in the clay content, which increases as the traveler passes north. Some of the lower lands of Petersborough were found to be quite different from the majority of the soils surrounding them. This difference has not yet been satisfactorily explained, but is, for the present, attributed to river action. The analysis of a sample will be found under Soils from the Middle of the Valley.

COMPOSITION OF SOILS FROM THE WEST SIDE, SOUTHERN HALF.

(Wellsville, Mendon, Petersborough and Cache Junction.)

LABORATORY NUMBER.	2058	2085	2071	2073	2163	2160	2166	Average.
Insoluble Residue............	82.42	83.73	78.07	75.98	74.80	78.25	75.73	78.42
Potash (K_2O)	0.77	0.76	1.34	1.50	1.43	1.34	1 09	1.18
Soda (Na_2O)...............	0.36	0.34	0.64	1.06	0.35	0.23	0.68	0.52
Lime CaO)	0.84	0.85	1.00	1.01	1.25	1.28	1.55	1.11
Magnesia (MgO)	0.61	0.64	0.98	0.72	0.86	1.16	0.51	0.78
Oxide of Manganese (Mn_3O_4)	0.00	0.01	0.07	0.00	0.07	0.00	0.04	0.03
Oxide of Iron (Fe_2O_3).......	2.84	2.89	3.09	3.38	3.84	3.19	3.85	3.29
Alumina (Al_2O_3)..........	4.41	4.85	6.43	7.34	8.11	6.28	8.28	6.53
Phosphoric Acid (P_2O_5)....	0.19	0.24	0.21	0.27	0.27	0.25	0.42	0.27
Carbon Dioxide (CO_2)......	.....	.....	.....	.....	.....	.....	.....	.....
Organic Matter...........	6.31	5.42	8.52	7.99	8.74	7.63	7.70	7.47
Totals....................	98.75	99.73	100.35	99.25	99.72	99.61	99.85	99.79
Humus...................	3.26	2.42	2.47	1.80	2.47	2.07	2.07	2.37
Nitrogen	0.115	.....	.....	.....	.....	.....	.....	.....
Water at 15° C...............	1.53	1.64	2.56	2.65	3.49	2.60	2.71	2.45

NOTES.

2058—This sample represents fairly well the soils between Wellsville and Mendon. A pure brown virgin soil. Depth 0.12 inches. Nothing is lacking in its supply of plant food; for a virgin soil it is remarkably rich in humus.

2085—Subsoil of the preceding. Depth 12-18 inches. Differs from the top soil only in being slightly darker in color, and containing less organic matter and humus.

2071—Representing the general nature of the soils found about three-fourths of a mile south of Mendon. Depth 0-12 inches. Cultivated. Light gray in color; very soft to the touch. Rich in all the essential plant foods.

2073—Subsoil of the preceding. Agrees with it in all its properties.

2163—Representative of the clay patches found about Mendon. Light brown and soft when dry; jet black when wet.

Depth 0.12 inches. A very rich soil which is, however, rather heavy to work.

2160—From the representative soils around Cache Junction. Very light gray in color, and almost free from grit. Depth 0-12 inches. Rich in potash, lime, phosphoric acid, organic matter and humus. More clayey than the soils farther south.

2166—Subsoil of 2160. Depth 12-18 inches. Same in color and physical properties.

13. SOILS FROM THE WEST SIDE, NORTHERN HALF.

(Benson and Newton).

GENERAL.

Just across the Bear River, north of Cache Junction, the country rises and forms a low range of hills that enclose a valley, open to the south, between themselves and the western mountains, and which is considerably above the level of Cache Valley proper. On the southeast corner of this swell, just behind Newton Butte, the town of Newton is located.

The district included under this heading represents the rising country around Newton and that lying under the swell to the southeast, in the curve made by Bear River as it turns west. To study this district, the best route is to cross Bear River below Benson, near the middle of the valley, and take a northwest course for Newton. The country lying north of the Bear and under the Newton swell is very extensive, but its cultivation has hitherto been limited by a want of water. Artesian wells have been driven in many cases, but with only a partial success. There are, however, some excellent dry farms in the region. Representative samples of the soils, beginning about one mile below the lower Benson bridge and ending just below the Newton Hill, were taken, and are found in the table under Nos. 2061, 2078, 2063 and 2064. They are very sandy loams, below the average of Cache County soils in potash, lime and phosphoric acid, though rich when compared with the soils of the eastern States. These soils will probably be the first to "give out" under the continuous grain cropping practiced here, although a correct system of rotation would extend their fertility to an indefinite period.

The remaining two samples, taken northwest and north of Newton, are similar to the soils around Cache Junction and

Mendon, in that they are loams containing a good proportion of clay. They are soils of high fertility.

COMPOSITION OF SOILS FROM THE WEST SIDE, NORTHERN HALF.

(Benson and Newton.)

LABORATORY NUMBER.	2061	2078	2063	2064	2081	2065	Average.
Insoluble Residue	89.93	88.78	86.47	87.40	75 24	78.49	84.38
Potash (K_2O)	0.47	0.67	0 68	0.71	1.37	1.51	0.90
Soda (Na_2O)	0.23	0.45	0.23	0.23	0.71	0.59	0.41
Lime (CaO)	0.46	0.99	0.67	0.69	1.31	1.06	0.87
Magnesia (MgO)	0.21	0.67	0 33	0.49	0.50	0.89	0.52
Oxide of Manganese (Mn_3O_4)	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Oxide of Iron (Fe_2O_3)	1.85	2.27	2.19	2.37	3.73	2.26	2.45
Alumina (Al_2O_3)	2.63	3.64	3.76	3.64	8 22	8.00	4.98
Phosphoric Acid (P_2O_5)	0.14	0.18	0.16	0.20	0.29	0.25	0.20
Carbon Dioxide (CO_2)	.....	.....	.....	.....	.....	.....	.....
Organic Matter	3.51	2.8[illegible]	5 13	4 37	7.64	7.02	5.08
Totals	99.41	10[illegible].47	99.62	100.10	99.01	100.07	99.79
Humus	....	0.94	1.84	1.61	2.07	2.37	1.77
Nitrogen	.....	.....	.....	0.134	.....	.....	.....
Water at 15° C.	0.78	1.12	1.45	1.45	2.65	2.75	1.70

NOTES.

2061—From the country lying between Benson and Newton. Depth 0-12 inches. Cultivated in wheat. Pale brown in color; gritty. The potash, lime and phosphoric acid are somewhat below the average for Cache Valley soils, but above the requirements for high productiveness.

2078—Subsoil to the preceding. Depth 12-18 inches. Somewhat richer in potash and lime than the top soil.

2063—Also taken from the soils that make up the country between Benson and Newton, but differs from 2061, as it has never been brought under cultivation. The native growth is sagebrush. Depth 0-12 inches. Pale brown in color and slightly gritty to the touch. Richer in potash, organic matter and humus than the cultivated soil. The difference is not likely to be due to the cultivation, but rather to the difference in the two soils, which were not taken from the same piece of ground.

2064—Subsoil of the preceding. Depth 12-18 inches. Does not differ materially from the top soil.

2081—A portion of the farming land of Newton lies northwest of the town towards the mountains. The shales and crystalline rocks of the mountains show their influence upon the soils which are less sandy. This sample was taken from the northwest fields of Newton. Depth 0-12 inches. Cultivated. Brownish gray in color, and faintly gritty to the touch. It is very rich in all plant foods. Its clay content is much higher than the lower soils.

2065—Considerable farming land is found between Newton and Clarkston. This sample was taken just north of Newton, in a line with the Newton reservoir. Depth 0-12 inches. Cultivated, dry farm. Brownish gray in color. A rich soil.

14. SOILS FROM THE NORTH END.

(Clarkston, Trenton, Lewiston and Richmond.)

GENERAL.

The district under this heading embraces a section across the north end of the valley. Clarkston is located higher up and farther north on the swell which carries Newton; almost due east, under the hill, lies Trenton; east, and across the valley, lies Lewiston, and farther east, near the mountains, lies Richmond.

The sample from Clarkston (No. 2169) resembles all the soils near the foothills on the west side. It contains considerable clay, is rich in lime and all other plant foods. A great variety of soils was noticed about Clarkston, due to the near proximity of the town to the mountains which prevents any general distribution and mixing of the soil varieties. The sample from Trenton (No. 2167) is representative of a large area lying under the Clarkston hill. Limestone ledges, which constitute the hill, are exposed, and the fragments from them have made the soil one of the richest lime soils in Cache county. The soil stands at the head of Cache soils in its content of potash, and among the best in phosphoric acid. It is altogether an excellent soil, but the same may with justice be said of nearly all the soils of the county. In the angle formed by the union of the Cub and Bear Rivers is a large area of fertile land which includes Lewiston. The last sample in this table represents the soils of Lewiston and the surrounding country. It is a very sandy soil but so rich in plant food that proper tillage will make it last for a longer period than human efforts ordinarily consider.

COMPOSITION OF SOILS FROM THE NORTH END.

(Clarkston, Trenton, Lewiston and Richmond.)

LABORATORY NUMBER.	2169	2167	2057	Average
Insoluble Residue	77.49	72.87	90.55	80.30
Potash (K_2O)	1.18	1.56	0.50	1.08
Soda (Na_2O)	0 59	0.73	0.17	0.49
Lime (CaO)	1.85	3.14	0.67	1.88
Magnesia (MgO)	0.88	0.67	0.13	0.56
Oxide of Manganese (Mn_3O_4)	0.08	0.04	0.00	0.04
Oxide of Iron (Fe_2O_3)	3.50	3.55	1.96	3 00
Alumina (Al_2O_3)	7.70	8.30	2.33	6.11
Phosphoric Acid (P_2O_5)	0.15	0.30	0.30	0.25
Carbon Dioxide (CO_2)	.....	.....	.....	.....
Organic Matter	6.94	9.22	3.07	6.41
Totals	100.26	100.38	99.68	100.11
Humus	1.27	.....	1.07	1.17
Nitrogen	.....	.....	0.027	.....
Water at 15° C	3.31	3.08	0.98	2.46

NOTES.

2169—Taken from the cultivated fields near Clarkston. Depth 0-12 inches. Virgin. Light brown with a tinge of yellow, and with no grit. A rich soil well provided with all the elements of plant food.

2167—Representative of the land lying under the hill, going east from Clarkston. Depth 0-12 inches. Virgin. Very light brown, with a faint tint of red, and very slightly gritty. A very rich soil, exceptionally rich in lime and potash.

2057—Represents the soils lying between Cub and Bear Rivers near Lewiston. Depth 0-12 inches. Cultivated but not fertilized. Light chocolate colored, gritty when dry. It is a very sandy soil and does not, therefore, contain much soluble material, yet it is plentifully supplied with potash and phosphoric acid. It is, in fact, a very fertile soil, as the crops obtained from it amply prove.

15. SOILS FROM THE EAST SIDE.

(Richmond to Millville).

GENERAL.

The district which embraces the whole of the east side of the county, consists essentially of two kinds of soil. The first and predominating kind is a rich loam, often largely admixed with clay, found in all low places near the mountains, and is general below the benches. The second is a gravelly and comparatively poor soil that covers the upper bench formation (chiefly the old deltas). The former class is represented by samples 2055 and 2059. They resemble the soils on the west side in their general composition, in the amounts of clay, potash and phosphoric acid, but carry rather more lime, from the limestone mountains that feed them. They are rich, fertile soils. The upper bench lands are represented by samples 90 and 93, which were taken from the college farm. They are high in lime, as would be expected from the admixture of limestone gravel, and comparatively poor in phosphoric acid. The content of potash is extremely low—this may be due to the method of analysis employed by Prof. Cutter, who analyzed these samples, but as no record of the method has been found this can not be asserted definitely.

COMPOSITION OF SOILS FROM THE EAST SIDE.

(Richmond to Millville)

LABORATORY NUMBER.	2055	90	93	2059	Average
Insoluble Residue	74.51	78.31	79.06	72.96	76.21
Potash (K_2O)	1.16	0.05	0.05	1.39	* 1 28
Soda (Na_2O)	0.26	0.08	0.07	0.73	* 0.50
Lime (CaO)	1.68	3.45	3.08	2.22	2.61
Magnesia (MgO)	0.54	2.29	2.52	1.47	1.71
Oxide of Manganese (Mn_3O_4)	0.00	.....	.....	0.00	.....
Oxide of Iron (Fe_2O_3)	3.74	* 7.54	7.06	4.29	* 4.01
Alumina (Al_2O_3)	8.84			9.09	* 8.97
Phosphoric Acid (P_2O_5)	0.20	0.12	0.10	0.18	0.15
Carbon Dioxide (CO_2)		0.15	0.18		....
Organic Matter	8.56	7.80	7.88	7.12	7.84
Totals	99.49	99.79	100.00	99.45	99.68
Humus	3.21	.....	.....	1.88	2.55
Nitrogen	0.249	0.065	0.072	0.188	0.144
Water at 15° C	4.04	5.40	9.34	3.02	5.45

*Samples 90 and 93 omitted in the averages of Soda, Potash, Iron and Alumina.

NOTES.

2055—Taken from the soil between Smithfield and Richmond, and is characteristic of nearly all the soils on the east side of the valley, under the upper benches. Depth 0-12 inches. Cultivated 18 years, and fertilized once. Brownish black in color. Does not differ much from other Cache County soils of the same degree of sandiness, except that it is rather richer in lime. The humus content is somewhat above the average, no doubt a result of the addition of barnyard manure.

90 and 91—Taken from the college farm, which is located

on upper bench land, and is, perhaps, the poorest of the cultivated soils in the county. Prof. Cutter, formerly chemist at the Station, who made the analyses, describes them as follows in the Second Annual Report, page 44: "The soil as a whole is very gravelly, but, along the southern edge of the farm the gravel almost wholly disappears and is replaced by a light sand. Sample 93 represents the majority of the gravelly plots. Sample 90 the sandy plot." The potash and soda are surprisingly low when compared with the analyses of soils taken elsewhere in the county. As nearly all the gravel on the bench consists of limestone fragments, the high proportion of lime is easily accounted for.

2059—Taken from the fields just north of Millville, and is representative of soils along the south part of the eastern side of the valley. Depth 0-12 inches. Virgin. Pinkish brown in color. A very fertile soil, containing more than the average of lime on account of the wash from the adjoining limestone cliffs.

16. SOILS FROM THE MIDDLE OF THE VALLEY.

(Benson, Petersborough, Etc.)

GENERAL.

The preceding tables and discussions have characterized all of the chief varieties of Cache County soils with the exception of those that lie in the lowest part, or middle, of the valley. This section, therefore, refers to the lands that extend about seven miles north and five miles south of Benson. Bear River runs through the northern portion of this district, and Logan River through the southern portion. The general nature of the soils is shown (Nos. 2046-2053) to be sandy, containing but a small amount of clay and lime; and comparatively a small amount of potash, and only a moderate amount of phosphoric acid. The testimony of those who have cultivated them is that they are very productive and "last" for many years. There are evidences which tend to show that these soils have been made by the sorting power of the rivers, as in past ages they have changed their channels, and are, therefore, "water washed." The only other class of soils, of importance, found in this district is represented by 2172, 2083 and 2084. Their content of clay equals that of the higher lying soils, and their content of lime is five to seven times greater. Their organic matter is also very high, and the other plant foods are present in abundance. Patches of this class may be found at various intervals in passing over the district. Their presence can be accounted for only by assuming that they are a sort of river deposit, the nearest approach to river silt found in the valley; and this is supported by the fact that they follow in a general way the courses of the rivers.

COMPOSITION OF SOILS FROM THE MIDDLE OF THE VALLEY.

(Benson, Petersborough, etc.)

LABORATORY NUMBER.	2172	2046	2047	2048	2049	2050	2051	2052	2053	2084	2083	Average.
Insoluble Residue	64.03	88.30	87.05	89.25	91.10	91.70	90.01	92.31	91.97	66.67	64.99	83.40
Potash (K_2O)	1.05	0.53	0.50	0.60	0.30	0.44	0.90	0.31	0.36	2.69	1.20	0.81
Soda (Na_2O)	1.41	0.47	0.41	0.21	0.12	0.20	1.24	0.17	0.22	0.69	1.11	0.57
Lime (CaO)	7.35	1.50	2.43	0.59	0.54	0.56	1.52	0.62	0.47	6.39	8.36	2.75
Magnesia (MgO)	1.37	0.21	0.58	0 73	0.33	0.41	0.18	0 31	0.26	0.66	1.56	0.60
Oxide of Manganese (Mn_3O_4)	0.05	0.20	0.07	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Oxide of Iron (Fe_2O_3)	2.73	2.22	4.63	2.29	1.85	1.93	1.79	1.86	1.67	3.30	2.95	2.47
Alumina (Al_2O_3)	8.93	2.54	2.00	3.24	2.45	2.43	2.11	2.14	1.82	8.13	7.27	3.91
Phosphoric Acid (P_2O_5)	0.21	0.20	0.25	0.18	0.18	0.20	0.25	0.18	0.15	0.23	0.26	0.21
Carbon Dioxide (CO_2)	5.54	.... .	.....	.....	.....	.....	.....	.....	.....	4.95	6.25	1.52
Organic Matter	8.13	3.58	2.03	3.34	2.69	2.34	1.86	1.86	3 26	7.11	5.47	5.31
Totals	100.80	99.75	99.95	100.50	99.63	100.21	99.86	99.79	100.18	100.82	99.47	100.09
Humus	.....	.	1.21	1.73	1.41	1.26	.....	1.27	1.15	1.44	1.35	1.33
Nitrogen	.....	0.067	0.089	.....	.....	0.268	.....	.....	0.128	.....	.....	.....
Water at 15° C	2.84	1.07	1.04	1.38	0.94	0.96	0.88	0.78	1.65	2 79	3.65	1.64

NOTES.

2172—Taken from the country that lies between Newton Butte and Smithfield, toward the center of the valley. It has all the appearance of having been formed by an overflow of Bear River. It represents a long stretch of country that may be traced along the course of Bear River, in the middle of Cache Valley. Depth 0-12 inches. Virgin. Brownish gray in color. It is a rich soil, with a very high per cent of lime. It is difficult to account for the existence of a deposit of lime soil in the bottom of a valley, and surrounded on all sides with soils comparatively poor in lime. The deposits of the Bear River sustain, no doubt, an important relation to the calcareous nature of the soil. It is not exceptionally rich in humus.

2046-2052 INCLUSIVE—Representative of the soils found in and about Benson; also characteristic of nearly all the sandy soils found along the course of Bear River. They are all of a light brown color. 2046 and 2047 are the soil and subsoil of the farm of Chas. Reese, of Benson.

2048—Is a top soil. 2049 and 2050 are soil and top soil. 2051 and 2052 are soil and top soil of the Benson farm of Mr. Wilford of Smithfield. They are all sandy soils but of high fertility.

2053—Taken to a depth of 24-36 inches in order to test the nature of the lower lying soil. It differs from the preceding soils in being of a higher and purer brown color, and in containing smaller amounts of soluble plant food.

2084—This sample belongs to the same class with 2172. Taken some distance below Petersborough, and a mile or more west of Logan River. Depth 0-12 inches. Virgin. Pure light gray in color and without grit; extraordinarily rich in potash, also rich in lime, phosporic acid and organic matter. It is highly fertile.

2083—Subsoil to 2084. Depth 0-12 inches. Corresponds with the top soil in its properties.

17. WHY NO MORE LIME IN CACHE SOILS?

Compared with the soils of other localities in Utah, the soils of Cache County are not remarkable in any respect, save it be in the small amount of lime which they contain. Wherever one goes within that part of the Great Basin included in Utah, with the exception of Cache County, a drop of acid added to the soil will produce a lively effervescence, showing the presence of an abundance of limestone. Here, in Cache, it is the exception to find a soil so rich in carbonates as to effervesce with acids. An explanation for this fact was sought for a long time without success, until a paragraph written by K. G. Gilbert came into mind, and connected itself with the lime content of the soils of this valley in such a way as to furnish a reasonable explanation.

During the time of Lake Bonneville, Cache Bay received from Bear River one-half of the total water received by the lake. The excess was passed through the Bear River Narrows into the main lake. By continual evaporation the lake water became concentrated, until the slightly soluble calcium carbonate or limestone began to be precipitated. The water in Cache Valley could not, however, reach such concentration, as the fresh water of Bear River flowing through it would tend to keep it fresh, or comparatively so. This reasoning, Prof. Gilbert says, was suggested by the absence (in Cache County), of any calcareous tufa deposits, which are generally distributed through the other valleys of the basin. It certainly seems that the same reasoning will apply in accounting for the different lime percentages in Cache Valley and the valleys that at one time were connected with it by the waters of Lake Bonneville.* The argument becomes strong when it is recalled that, outside of Cache County, the soils of the Bonneville Basin are so rich as to require a special explanation, which is readily furnished by the saturation of the lake water and the subsequent precipitation of lime from it.

18. SUMMARY.

The following, in connection with the table of analyses, is a very brief summary of the facts brought out in the preceding pages.

1. Cache Valley, and many of the western valleys of Utah, were formerly filled with water, forming a large lake, known as Lake Bonneville. The agricultural soils of the valley are located, mainly, on the old lake bottom.

2. The general nature of Cache Valley soils is that of a moderately clayey loam. The soils on the hillsides, which have

*For a more detailed statement showing that the same condition would prevail whether the lake had an outlet or not, see U. S. Geological Survey, Monograph I, Lake Bonneville, by K. G. Gilbert, pages 167 and 197.

been influenced by the seasonal wash from the mountains, contain most clay. The soils along the middle of the valley are more sandy, although occasional tracts of clay soils occur.

3. Cache Valley soils do not differ much in composition from the majority of the soils of the arid part of America. They are abundantly supplied with all the essential plant foods, and, with proper tillage will "last" for an indefinite period. Phosphoric acid is present in least abundance.

4. There is less lime in Cache Valley soils than in any other soil district within the Bonneville Basin. This is due to the freshening influence of Bear River, during the time of Lake Bonneville, which prevented a precipitation of lime from the water of the valley.

SUMMARY OF AVERAGES.

Composition of Cache County Soils.

LOCALITY.	South End	West Side South	West Side North	North End	East Side	Middle of Valley	Average for Cache Co.
Samples Analyzed.	6	7	6	3	4	11	37
Insoluble Residue	80.30	78.42	84.38	80.30	76.21	83.40	81.09
Potash (K_2O)	0.95	1.18	0.90	1.08	1 28	0.81	0.99
Soda (Na_2O)	0.59	0.52	0.41	0.49	0.50	0.57	0.53
Lime (CaO)	1.12	1.11	0.87	1.88	2.61	2.75	1.78
Magnesia (MgO)	0.53	0.78	0.52	0 56	1.71	0.60	0.73
Oxide of Manganese (Mn_3O_4)	0.02	0.03	0.00	0.04	0.00	0.05	0 03
Oxide of Iron (Fe_2O_3)	3.18	3.29	2.45	3.00	4.01	2.47	2.95
Alumina (Al_2O_3)	5.79	6.53	4.98	6.11	8.97	3.91	5.61
Phosphoric Acid (P_2O_5)	0.25	0.27	0.20	0.25	0.15	0.21	.22
Carbon Dioxide (CO_2)	.....	.....	.....	.....	.	1.52	....
Organic Matter	7.14	7.47	5.08	6.41	7.84	5.31	6.34
Total	100.03	99.79	99.79	100.11	99.68	100.09	99.93
Humus	3.01	2.37	1.77	1.17	2.55	1.33	1.99
Nitrogen	.....	.....	.....	.....	.....	.....	.....
Water at 15° C.	2.21	2.45	1.70	2.46	5.45	1.64	2.37

D.—THE SOILS OF SANPETE COUNTY.

19. DESCRIPTION OF THE VALLEY.

LOCATION AND FORM.

Considering the extreme State boundaries, Sanpete County is almost the mathematical center of Utah. Sanpete Valley, which is the agricultural portion of the county, measures about fifty-five miles, from north to south, with a maximum width of about fifteen miles. The high mountains on the east form a part of the high plateaus of Utah; on the west the mountains are smaller, after becoming mere hills, until the southern limit of the Wasatch range of mountains is reached, ten or fifteen miles to the northwest. At the north, the valley is closed, but opens to the south for the first third of its length. Here it is at its widest; and here, also, it sends a fork to the northwest. From this point it grows narrower until the narrowest point is reached, about one-third of its length from the southern boundary. From now on, it becomes more elevated and widens, though the opening made is so filled with clay hills, or "bad lands," as to destroy the idea of a valley. Its south end opens into the valley of the Sevier River.

RIVERS, TOWNS, ETC.

The Sanpitch River rises in the north mountains and travels down the valley until within about five miles of the southern limit, when it turns to the west and empties into the Sevier River. On its descent of the valley it is fed by numerous smaller streams that spring from the eastern, and, in the north, from the western mountains.

The whole valley inclines to the west, and the lowest bottom lands are, therefore, toward the western foothills. The land here is very low and, as a result, the drainage from the upper lands has accumulated with the formation of a long stretch of wet soil, often passing into swamps. Much of the water in this low portion evaporates before it can reach the river, and leaves behind its mineral content. Alkali crusts are, consequently, very abundant along the edges of the marshes, especially in dry seasons. Just below Manti, on the lower edge of the wet lowlands, is a large saleratus plat, from which considerable quantities of the mineral are collected and sold to manufacturers who employ the carbonate of sodium. In the south end, where the country rises, the soil is dry, but alkali may be seen everywhere encrusting the weathered faces of the soft shale hills.

The villages below Mt. Pleasant are all built on the east side of the valley. The inhabitants who, like the majority of the population of Utah, are thrifty Mormon settlers, number about 16,000. The staple crops are wheat, lucern and potatoes.* The acreage of cultivated land was, in 1896, about 27,000. The valley is very fertile; it ranks second only to Cache Valley as a great wheat producing district.

20. THE SOURCES OF SANPETE VALLEY SOILS, ETC.

The drainage of Sanpete Valley passes into the Sevier River, which empties into Sevier Lake. When, as described in preceding pages, the western valleys of Utah were filled with water, the lower part of the basin of the Sevier was also filled. Sanpete Valley, however, owing to its higher elevation, was not submerged, and the peculiar markings on the mountain sides are there lacking, as well as the constant gentleness of outline, which characterize Cache Valley. It must be mentioned that other evidences, which are very marked, prove that at a period previous to Lake Bonneville, Sanpete Valley must have been filled with water. The rocks that surround the valley are very uniform in character, and made up chiefly of a calcareous shale, broken in places by white marl and sandstone. The soils have been washed down from the mountains into the lower places; and, from the uniform nature of the rocks, would not differ greatly among themselves. The analyses to be presented will show that the first marked differences occur in the north end of the valley, where the Wasatch range of mountains contributes some of the material.

21. SOILS FROM FAIRVIEW, MT. PLEASANT AND MORONI.

GENERAL.

Beginning at Fairview and going southward to Mt. Pleasant, several varieties of soil were observed. Aside from the calcareous soil, characteristic of the whole valley, a sandy belt predominates about four miles north of Mt. Pleasant. This is the poorest cultivated soil (1819) yet encountered in Utah. Samples 1818 and 1817 represent fairly well the soils around Mt. Pleasant. They all seem to be high in lime and other plant foods, but low in clay. Going southwest from Mt. Pleasan he soils begin, very gradually, to change; as Moroni is approached, becoming more clayey. Sample 1816 represents this variety.

*The yields for 1894 were as follows: Wheat, 353,257 bushels; lucern, 27,985 tons; potatoes, 76,472 bushels.

There are more kinds of soils around Mt. Pleasant than anywhere else in the county, and they are all fertile.

COMPOSITION OF SOILS FROM FAIRVIEW, MT. PLEASANT AND MORONI.

LABORATORY NUMBERS.	1819	1818	1817	1816	Average
Insoluble Residue	92.34	67.93	72.45	54.88	71.90
Potash (K_2O)	0.27	0.68	0.72	0.80	0.62
Soda (Na_2O)	0.09	0.55	0.37	0.87	0.47
Lime (CaO)	0.37	9.81	10.65	13.09	8.48
Magnesia (MgO)	0.13	0.73	0.07	0.84	0.45
Oxide of Manganese (Mn_3O_4)	0.06	0.20	0.41	0.24	0.23
Oxide of Iron (Fe_2O_3)	1.67	2.33	1.11	3.62	2.18
Alumina (Al_2O_3)	2.11	4.93	2.84	8.02	4.48
Phosphoric Acid (P_2O_5)	0.16	0.21	0.11	0.22	0.18
Carbon Dioxide (CO_2)	.....	7.75	8.26	11.21	6.81
Organic Matter	2.01	4.95	2.98	6.01	3.99
Total	99.21	100.07	99.97	99.80	99.76
Humus	1.12	2.96	1.40	3.15	2.16
Nitrogen	.....	0.159	.....	.....	.....
Water at 15° C	0.54	1.52	0.67	3.64	1.59

NOTES.

1819—Taken about four miles north of Mt. Pleasant on the road to Fairview. Depth 0-12 inches. A very sandy, virgin soil, carrying grass, willows, etc. Pure, red brown in color. Fairly well supplied with the essential plant foods, though when compared with the majority of Utah soils, it is low in potash and lime.

1818—Taken from Mt. Pleasant fields just west of the town. Depth 0-12 inches. Virgin. Natural herbage, sage brush and "yellow top." Color light gray; soft and very fine. A fertile soil, rich in lime, containing a moderate proportion of clay.

1817—Taken about two miles west of Mt. Pleasant on the road to Moroni. Depth 0-12 inches. Virgin, with natural herbage like 1818. Pale gray in color, coarse; showing particles of white or gray limestone throughout its mass. This also is a very rich soil, shading gradually into 1818. It is less clayey.

1816—Taken four miles west of Mt. Pleasant, on the Moroni road. Depth 0-12 inches. Virgin. Light gray, almost white, in color; very soft to the touch. A very rich soil containing a high proportion of lime, and quite clayey, compared with the soils further to the east.

22. SOILS FROM SPRING CITY AND CHESTER.

A few miles south of Mt. Pleasant, Spring City is located. Very few soil varieties were found here; sample 1821 represents the predominating kind. It is very rich in lime and heavily charged with clay. The potash is not quite as high as the average for Utah soils, but is sufficient for the best results. West of Spring City is the town of Moroni. The soils in this place, as shown by the analysis of sample 1824, do not differ much from the soils of Spring City, with the exception that they contain more clay. It seems to be a rule that the soils to the west are more clayey than those of the east side of the valley.

COMPOSITION OF SOILS FROM SPRING CITY AND CHESTER.

LABORATORY NUMBER.	1821	1824	Average
Insoluble Residue	40.45	45.27	42.86
Potash (K_2O)	0.51	0.65	0.58
Soda (Na_2O)	0.46	0.43	0.45
Lime (CaO)	22.54	17.35	19.95
Magnesia (MgO)	1.29	0.29	0.79
Oxide of Manganese (Mn_3O_4)	0.09	0.14	0.12
Oxide of Iron (Fe_2O_3)	2.79	2.11	2.45
Alumina (Al_2O_3)	10.57	13.14	11.86
Phosphoric Acid (P_2O_5)	0.17	0.15	0.16
Carbon Dioxide (CO_2)	17.02	13.88	15.45
Organic Matter	3.85	6.62	5.24
Totals	99.74	100.03	100.03
Humus	1.74	2.33	2.04
Nitrogen	0.131	0.118	0.125
Water at 15° C	1.34	1.56	1.45

NOTES.

1821—Taken from Spring City, just south of the railroad depot. Depth 0-12 inches. Virgin. Pale, reddish brown in color, showing coarse grains of limestone. A rich soil, with an extremely high per cent of lime, and a high proportion of clay.

1824—Taken from the farm of James Allred. Chester. Depth 0-12 inches. Cultivated. Pale brown in color, homogeneous to the eye. Rich in lime and clay, and the essential plant foods.

23. SOILS FROM EPHRAIM.

GENERAL.

The soils of Ephraim are represented by samples 1826 and 1827. They contain much lime, though not so much as the soils to the north; are richer in clay, as a district, than any other locality of Sanpete County. Potash, phosphoric acid and humus are abundant. To the north of Ephraim, beyond the cultivated fields, are vast stretches of rich gravelly land that as yet have not been used by the farmers.

COMPOSITION OF SOILS FROM EPHRAIM.

LABORATORY NUMBER.	1826	1827	Average.
Insoluble Residue	50.74	49.34	50.04
Potash (K_2O)	0 95	1.24	1.10
Soda (Na_2O)	0.54	0.92	0.73
Lime (CaO)	14.89	13.16	14.03
Magnesia (MgO)	0.42	0.26	0 34
Oxide of Manganese (Mn_3O_4)	0.10	0.08	0.09
Oxide of Iron (Fe_2O_3)	4.03	3.73	3.88
Alumina (Al_2O_3)	13.11	13.19	13.15
Phosphoric Acid (P_2O_5)	0.20	0.24	0.22
Carbon Dioxide (CO_2)	11.25	10.46	10.86
Organic Matter	6.13	7.16	6.65
Totals	100.36	99.78	100.07
Humus	1.62	2.03	1.83
Water at 15° C.	1.94	2.69	2.32

NOTES.

1826—Taken from the farm of J. A. Anderson, Jr., just north of Ephraim. Depth 0-12 inches. Cultivated. Very light brown in color, showing occasional grains of white limestone. Contains an abundance of all the essential plant foods, and a high proportion of clay.

1827—From the farm of J. A. Anderson, Jr., just north of Ephraim. Depth 0-12 inches. Virgin; growing sagebrush. Very light, pure brown in color. Like the preceding soil, it is rich in clay and the essential plant foods.

24. SOILS FROM MANTI.

Manti lies south from Ephraim. Its soils are rich in lime, potash, phosphoric acid and humus; but contain less clay than the soils to the north. Alkali, and alkali spots, can be studied very well in the lower fields. On fertile lands there may be several large spots of heavy alkali, that, according to the old settlers, have been there ever since the settlers first came. The soil about them is normal in every respect. The subsoils of other lands are heavily charged with alkali, but it does not give much trouble "by rising." The study of the "alkali question" near Manti, is involved, and has not yet been finished. Warm springs and lime deposits show the effect of volcanic activity. It may be that the alkali spots and the saleratus flat bear definite relations to extinct hot mineral springs. The fertility of the soils that are not troubled with an excess of alkali is very high.

COMPOSITION OF SOILS FROM MANTI.

LABORATORY NUMBER.	1808	1807	1809	*1805	*1806	*Average.
Insoluble Residue............	61.03	63 96	53.69	55.27	38.56	59.56
Potash (K_2O)	0.58	0.67	1.03	0.58	0.95	0.76
Soda (Na_2O)...............	0.67	0.56	0.47	5.24	4.63	0.57
Lime (CaO)	9.91	9.53	14.01	12.84	22.05	11.15
Magnesia (MgO)	1.40	1.68	1.20	0.71	0.85	1.43
Oxide of Manganese (Mn_3O_4)	0.05	0.10	0.03	0.05	0.02	0.06
Oxide of Iron (Fe_2O_3)...	3.07	2.51	2.88	2 21	2.39	2.82
Alumina (Al_2O_3)...........	8.23	7.95	8.11	6.21	5.62	8.13
Phosphoric Acid (P_2O_5)....	0.17	0.18	0.19	0.14	0.16	0.19
Carbon Dioxide (CO_2)......	10.52	7.46	10.95	14.64	19.18	9.65
Organic Matter............	4 63	5.18	7.26	2.25	5.08	5.69
Totals..................	100.27	99.79	99.82	100.14	99.49	99.92
Humus	2.43	2.29	3.16	1.15	2.41	2.63
Nitrogen	0.070	0.152	0.145	0.070	0 104	0.108
Water at 15° C..................	2.39	1.53	2.17	1.19	1.00	2.03

*Samples 1805 and 1806 not included in the averages.

NOTES.

1808—From the farm of Bishop Hans Jensen, near Manti. Depth 0-12 inches. Cultivated forty years; never fertilized. Of a dirty pink color. A rich calcareous soil containing considerable clay.

1807—From the farm of Bishop Hans Jensen, near Manti. Depth 0-12 inches. Cultivated and fertilized. In color, a dirty pink. A rich soil, similar to the preceding.

1809—From the "old field," one mile north of Manti. Cultivated forty-five years and never fertilized. Depth 0-12 inches. Pale brown in color. A rich, productive soil, similar to the two preceding ones.

1805—Many of the lands near Manti are underlaid by a subsoil, rich in alkali. With insufficient water the alkali often rises to the surface with disastrous results to the crop. This sample was taken to a depth of 12-24 inches, in a fertile field not far above the saleratus flats of Manti.

1806—Taken from the saleratus beds southwest of Manti. Salt grass and wire grass grow in many places of the beds where the mineral is not too strong. Depth 0-12 inches. Color, pale gray, almost white, showing distinct particles of limestone.

25. SOILS FROM THE SOUTHERN PART.

(Sterling, Mayfield, Willow Springs, Gunnison, Etc.)

GENERAL.

The country between Manti and the southern boundary of county is made up chiefly of clay hills, deeply weathered, that look very much like the water-cut country to the southwest, outside of the basin. The first settlement to the south of

COMPOSITION OF SOILS FROM THE SOUTHERN PART OF THE VALLEY.

(Sterling, Mayfield, Willow Springs and Gunnison.)

LABORATORY NUMBER.	1825	1811	1812	1813	1814	Average.
Insoluble Residue	52.91	59.07	61.24	56.02	58.86	57.62
Potash (K_2O)	0.81	0.75	0.60	1.25	0.95	0.87
Soda (Na_2O)	0.83	0.56	0.70	1.14	0.83	0.81
Lime (CaO)	13.17	13.99	13.24	13.76	13.17	13.47
Magnesia (MgO)	1.80	0.46	0.59	0.75	0 29	0.78
Oxide of Manganese (Mn_3O_4)	0 07	0.03	0.14	0.42	0.49	0.23
Oxide of Iron (Fe_2O_3)	2.37	3.16	2.76	2.86	2.11	2.65
Alumina (Al_2O_3)	11.43	7.38	7.02	8.41	8.05	8.46
Phosphoric Acid (P_2O_5)	0.17	0.23	0.20	0.16	0.12	0.18
Carbon Dioxide (CO_2)	11.28	11.01	10.59	10.56	10 89	10.87
Organic Matter	4.31	3 13	2.65	4.85	3.80	3.75
Totals	99.48	99.75	99.73	100.18	99.56	99.75
Humus	1.59	1.78	1.57	2.21	1.89	1.81
Nitrogen	.....	0.089	.....	0.128	0.084	.....
Water at 15° C	2.34	1.99	1.73	1.51	1.28	1.77

Manti, is Sterling. Sample 1825 is representative of the soils found there. They are rich soils, rather heavily charged with clay, though less than is found at Ephraim. At Mayfield, south of Sterling, sample 1811, which is representative of a large tract of country, was taken. The clay content is lower than at Sterling, and the essential plant foods are present in abundance. South of Mayfield is a comparatively large desert devoid of water. To the traveler, unfamiliar with arid America, it would seem impossible to produce crops upon it. The analysis of a sample taken there (1812) shows it, however, to be a rich soil that would yield heavily if water could be obtained. Southwest of Mayfield, about five miles, a number of farms are found along the course of a little stream known as Willow Springs. A railroad station near by is called Axtell. A large tract of even, fertile country stretches from Willow Springs up to Gunnison, which is west and slightly north of Mayfield. Samples 1813 and 1814 represent this stretch of country. It is very rich in potash and lime, moderately rich in clay, and well supplied with humus. The phosphoric acid content is a little lower than most Utah soils, but in rich abundance for crop uses. The country limited by Mayfield, Willow Springs, the Sevier and Gunnison is, perhaps, as ideal a piece of land as is found in Utah, as far as climate and composition of the soils are concerned. Near Gunnison occurs a sandy variety of soil, underlaid by sandstone, the sample of which has unfortunately been lost.

NOTES.

1825—Taken from Daniel Witbeck's farm at Stirling. Cultivated in wheat and oats, but never fertilized or fallowed. There are clay spots throughout the field, which seem to increase in size as cultivation proceeds. Depth 0-12 inches. Pale yellow-red in color, showing numerous white or gray particles of limestone. A rich calcareous soil, with nearly as much clay as the soils about Ephraim and Spring City.

1811—Soil from the farm of Thomas Haywood, just north of Mayfield. Cultivated and slightly fertilized. Depth 0-12 inches. In color, pale yellow with a tinge of brown; particles of calcareous rock throughout its mass. This is a rich soil, not differing much from the other soils of the valley. The cultural results are 50 to 60 bushels of wheat the first year after fallowing; the second year it falls to 35 to 40 bushels.

1812—Virgin soil from the desert between Mayfield and Salina, not far beyond milepost 16 from Manti. No vegetation except a little sagebrush. Depth 0-12 inches. Pale brownish yellow in color; quite uniform in structure to the eye, but showing occasional grains of limestone. It is a very rich soil, and similar to the soils around Mayfield.

1813—Virgin soil from the farm of Chas. Boshart, at Willow Springs. Natural herbage is sagebrush and shad scale. The soil is underlaid by a deposit of calcareous sand. Depth 0-12 inches. Color, pale reddish yellow. The analysis, as well as the cultural results, show this to be a very rich soil. The new land does as well, if not better than the fertilized.

1814—Subsoil to the above. Depth 12-18 inches. Agrees with the top soil in all its properties.

26. WHY SO MUCH LIME IN SANPETE SOILS?

The soils of Sanpete Valley, compared with those of Cache Valley, contain seven times more lime, and they are more calcareous than the majority of soils from the Salt Lake or Bonneville Basin. Many of the marls of other states, used for fertilizing purposes, do not contain more lime than the soils of this valley. One cause of the calcareous nature of these soils lies in the highly calcareous character of the rocks from which they have been made. The shales that constitute the greater part of the High Plateaus are very rich in limestone—often as much as 75 per cent being present. From the microscopic appearance it appears that much of the lime in Sanpete soils has been precipitated from water. This strengthens the belief that Sanpete Valley was at one time filled with water, concentrated beyond the saturation degree for lime. No systematic study of the soils of the Great Basin has yet been made, but, as far as our knowledge goes, the soils of this district are invariably very rich in lime. The question of lime in the arid west is at the present being studied at the Station.

27. SUMMARY.

The following, with the table of averages, will give a very brief summary of the facts brought out in the discussion of Sanpete soils:

SUMMARY OF AVERAGES.

Composition of Sanpete County Soils.

LOCALITY.	North End	Spring City, etc.	Ephraim.	Manti.	South End.	Average for Sanpete Co
Samples Analyzed.	4	2	2	5	5	18
Insoluble Residue	71.90	42.86	50.04	59.56	57.62	58.85
Potash (K_2O)	0.62	0.58	1.10	0.76	0.87	0.78
Soda (Na_2O)	0.47	0.45	0.73	0.57	0.81	0.62
Lime (CaO)	8.48	19.95	14.03	11.15	13.47	12.50
Magnesia (MgO)	0.45	0.79	0.34	1.43	0.78	0.84
Oxide of Manganese (Mn_3O_4)	0.23	0.12	0.09	0.06	0.23	0.16
Oxide of Iron (Fe_2O_3)	2.18	2.45	3.88	2.82	2.65	2.71
Alumina (Al_2O_3)	4.48	11.86	13.15	8.13	8.46	8.41
Phosphoric Acid (P_2O_5)	0.18	0.17	0.22	0.19	0.18	0.19
Carbon Dioxide (CO_2)	6.81	15.45	10.86	9.65	10.87	10.14
Organic Matter	3.99	5.24	6.65	5.69	3.75	4.83
Total	99.76	99.89	100.07	99.92	99.75	99.85
Humus	2.16	2.04	1.83	2.63	1.87	2.14
Nitrogen	.....	.....	.....	.....	....	.....
Water at 15° C.	1.59	1.45	2.32	2.03	1.77	1.83

1. Sanpete valley was not submerged at the time of Lake Bonneville. It was, however, filled with water at an earlier period.

2. The soils of Sanpete Valley have been formed chiefly from the calcareous shales of the High Plateaus of Utah, on the northern edge of which the valley is situated.

3. The general nature of Sanpete Valley soils is that of a rather clayey soil mixed with an extraordinarily large amount of lime. The excess of lime obscures the properties of the clay.

4. In composition, the soils of Sanpete Valley differ from recorded analyses of soils from other portions of the Great Basin, in that they contain more lime. Otherwise they are not strikingly different. They are extremely fertile soils that "last" for an indefinite period. As in Cache Valley soils, the phosphoric acid is least abundant.

5. The large amount of lime in the soils of Sanpete County is due, chiefly, to the calcareous nature of the mountains from which the soils have been made, and partly to the precipitation of lime from the water which once filled the valley.

E.—GENERAL SUMMARY.

28. COMPOSITION OF SOILS FROM VARIOUS PARTS OF AMERICA.

For the purpose of ready comparison the following table has been constructed. It shows that Utah soils rank very high in the amounts of plant food which they contain.

COMPOSITION OF SOILS FROM VARIOUS PARTS OF AMERICA.

LOCALITY.	Cache Co. Utah.	Sanpete Co. Utah.	* South Florida.	† Minnesota.	‡ Arid America.	‡ Humid America.
Samples Analyzed.	37	18	33	200	313	466
Insoluble Residue	81.09	58.85	95.99	79.51	76.14	87.69
Potash (K_2O)	0.99	0.78	0.01	0.28	0.73	0.22
Soda (Na_2O)	0.53	0.62	.....	0.25	0.26	0.09
Lime (CaO)	1.78	12.50	0.28	2.16	1.36	0.11
Magnesia (MgO)	0.73	0.84	.....	0.55	1.41	0.23
Oxide of Manganese (Mn_3O_4)	0.03	0.16	.....	.....	0.06	0.13
Oxide of Iron (Fe_2O_3)	2.95	2.71	.....	2.68	5.75	3.13
Alumina (Al_2O_3)	5.61	8.41	.....	5.20	7.89	4.30
Phosphoric Acid (P_2O_5)	0.22	0.19	0.16	0.24	0.12	0.11
Carbon Dioxide (CO_2)	.....	10.14	.....	.....	.....	.....
Organic Matter	6.34	4.83	.....	7.00	4.95	3.64
Totals	.....	.....	.....	.....	.....	.....
Humus	1.99	2.14	0.64	.....	1.84	2.39
Nitrogen	.....	.....	0.041	.....	.....	.....
Water at 15° C	2.37	1.83	.....	.....	.....	.....

* Bulletin 43. Florida Exp. Station, by A. A. Persons.

† Bulletin 41. Minnesota Exp. Station, by H. Snyder.

‡ Relations of Soil to climate, by E. W. Hilgard. Bull. 3, U. S. Weather Bureau.

29. CONCLUSION.

In conclusion the writer wishes to express his thanks to Prof. J. H. Paul who, as Station Director, authorized the work and aided its progress by much kind encouragement; and to President J. M. Tanner, who made it possible to extend the investigation to various parts of the State. Favors, that have aided the work materially, have been received from Director Luther Foster, Prof. F. B. Linfield, F. A. Wadleigh of the Denver & Rio Grande Railway, and from numerous citizens residing in the districts that have been studied.

The work recorded in this bulletin is but an humble beginning; yet, if it serves only to arouse curiosity, and create interest in an important subject, it will have decided value. The work should be prosecuted systematically, on broader lines, until a complete agricultural map of the State can be prepared for the use of residents of the State, and of prospective settlers.

F.—SOME SUGGESTIONS FOR MAINTAINING AND INCREASING THE FERTILITY OF UTAH SOILS.*

30. INTRODUCTION.

Wherever one goes in Utah the statement is heard that "the soils are not now so productive as they were when we first settled here." Year by year this experience grows more definite, and insisting appeals are made to suggest a remedy. The virgin soils of Utah were of such extraordinary fertility that it could not be expected that they would long maintain it when subjected to cropping; and the lands that are spoken of as "worn out" or "wearing out" are, in many cases, very fertile lands that yield crops two or three times as great as the average for the United States. It is a fact that continuous cropping has, on many lands, diminished the yields one-half or even two-thirds. Such a decrease means a material loss to the farmer; especially when better methods of cultivation can prevent it.

There are, of course, cases in which lands have been rendered wholly unproductive for certain crops, but they can be referred to causes other than cropping. The bottom lands of the Utah valleys, for instance, are rapidly being abandoned as the upper lands are farmed and irrigated, and the drainage from irrigation settles in the lowest places. So, also, in places, irrigation of the higher lying lands has brought up the "alkali" in the lower farms, and thus rendered them unproductive. Such cases, however, do not "wear out" the land; and they merit a special discussion which it is not intended to give in this place.

The suggestions to be offered here are for application to such lands as are not troubled with an excess of water or alkali, or with hardpan; but which, while all conditions seem as favorable as formerly, cease to give the heavy yields that were obtained during the first years of cultivation.

31. HISTORY OF UTAH SOILS.

A brief review of the origin of Utah soils will serve as a

*Prof. F. B. Linfield of the Utah Station, has an instructive and suggestive article on this subject in the Orange Judd Farmer, of November 13th, 1897. It has been reprinted in many Utah papers, and it is worthy of careful reading and study.

good introduction to what will follow. All the soils of Utah, with a few exceptions, are alluvial in their nature: that is, they are at a distance from the rocks from which they were made. The mountains have been the source of all Utah soils. As the rocks of the mountains were subjected to the action of frost and water, they were broken down into small particles, which the rains washed downward into the valleys. Many centuries of this process filled the valleys with soil at the expense of the mountains. This accounts for the great depth of Utah soils: which, in one case at least, amounts to 500 feet. The rocks of the mountains were rich in all mineral plant food, and the soils resulting from them would, consequently, be equally rich. As time passed, the fertility did not diminish, as would be the case in most places on the earth's surface, but rather increased. In regions of abundant rainfall much of the mineral plant food is washed out of the soil into the country drainage and finally into the ocean. In such a locality the soil cannot increase in fertility; for the loss of plant food by drainage will balance any gain by weathering. In arid districts, such as Utah, the rain penetrates the soil to a depth of a few feet only and is removed from the soil again by evaporation. As no drainage occurs in such districts, there will be no loss of plant food from the soil, but, on the contrary, as the weather acts on the soil particles to render them soluble, the quantity of available plant food increases. This difference between the soils of moist and arid climates is well illustrated by analyses made of soils from the two regions. Prof. Hilgard* has made a collection of analyses of soil samples taken from arid and humid districts. His averages show 11.87 per cent soluble material for the humid region and 23.65 per cent for the arid. All the constituents of the soluble material would vary approximately in the same ratio.‡

32. NITROGEN AND HUMUS IN UTAH SOILS.

The rocks from which Utah soils have been made were deficient in only one essential plant food; namely, nitrogen. This element was present, though not in great abundance. No loss of nitrogen occurred, however, so that whatever was given to the soils, from the rocks, remained there; and, as the rains fell and were evaporated from the soil, much of the nitrogen and other soluble plant foods were brought near the surface and there concentrated. As a result many of the virgin soils of the

*Relations of Soil to Climate, by E. W. Hilgard. Bulletin 3, U. S. Weather Bureau.

‡Bulletin 43 of the Florida Exp. Station, by A. A. Persons, gives 4.01 per cent of soluble materials as an average of the analyses of 37 samples of Florida soils.

State show per cents of nitrogen that compare favorably with soils that are richer in vegetable matter. The amount of nitrogen and humus also increased as time passed on. Inside of the Great Basin, after the lakes receded, the old lake bottoms and hillsides became covered with a luxuriant vegetation. Plants grew to maturity, died and fell to the ground; and new generations succeeded. The old settlers of the State often relate how the valleys looked when they first came into them; how they were covered with bunches of grass that sometimes stood three feet high; and how they could stake out a horse with a lasso rope, and he find sufficient food for a night. The writer has observed on the dry bench land, where a piece of land has been fenced to keep the cattle out, how the "blue grass" will spring up until, in a few years, it will hide the sage brush. Among the many plants that covered the Utah valleys, during the many centuries that came and departed before the first settlers arrived, were many species of the family *leguminosæ*, which has the power of enriching the soil with nitrogen. From all this it is not surprising to find liberal supplies of nitrogen and of humus in many of the soils of Utah. The dry, rather hot climate, tended naturally to reduce the organic matter not humified. Beyond the Great Basin, and on its rim, the amounts of nitrogen and humus are not so large; for here the climate was drier and vegetation did not flourish. In fact, the writer, in common with those who have traversed the wastes of Western America, has traveled for days without seeing a trace of vegetation, and such soils are almost devoid of organic matter and humus, and contain but small quantities of nitrogen.

33. WHY DO SOILS WEAR OUT?

The soils of Utah, especially within the Basin, are rich in *all* plant foods. Why do they wear out? or better, why do the yields diminish after some years of cultivation? The virgin soils were rich in plant food that was in a very soluble condition, and which would be used by the plants first of all. As successive crops were raised upon the land, this easily available food became exhausted and the plants were compelled to fall back upon the more insoluble portion for their food supply. With the passage of the seasons, the plant food that remained would be in a more and more insoluble condition; and, consequently, the plants would feed with increasing difficulty. This led to a decrease of the yields of crops on the lands, for a crop is, roughly, directly dependant upon the amount of easily available plant food present.

The decrease in yield did not at all imply a deficiency of plant food; simply a diminished amount of *available* plant food. A case in point is the following: A piece of land had been cultivated continuously in wheat for twelve years, and the yield had fallen to 30 bushels per acre. It was then given one summer's fallow with frequent and thorough plowing. The next spring, wheat was put in again, with a yield of 75 bushels per acre. During the year of fallow or rest the atmospheric agencies had acted upon the soil, turned several times by the plow, to render the plant food in the soil more soluble, or available. The next crop then found a large amount of available food, to which it responded at once, with the magnificent result above recorded. The next year's crop was smaller; and it continued to diminish, year by year, until another fallow was given it, when the crop again made a prompt response. That this is a wise method of farming, is not asserted, but the results show that a decrease in the crop yield does not necessarily mean a deficiency of plant food in the soil.

The question before the cultivators of Utah soils is then, how can I best maintain an abundant supply of soluble or available plant food in my fields? The answer to this question can be stated simply: *By a rational method of rotation of crops, and by returning to the soil the greatest possible amount of the substances taken from it.*

34. EFFECT OF GROWING THE SAME CROP CONTINUOUSLY.

To grow the same crop upon a field year after year is the very worst way of treating the soil. Every plant has its own peculiar habit of life. It feeds more heavily upon one substance than upon another; it attacks the soil particles in its own characteristic manner; its peculiar root system will use only a certain portion of the soil, and only to a certain depth; in short, it will exhaust the land, making it weak and worn in one way, leaving it fertile in all other ways. When, now, weeds settle upon the lands, those having habits different from the crop grown, will find a rich soil for their growth and will flourish, always with great detriment to the crop desired by the husbandman, and often with its total destruction. The first consideration, therefore, in a system of rotation of crops, is to exhaust the soil as uniformly as possible. This may be done by following, for instance, a shallow rooted with a deep rooted crop, in order to exhaust the upper and lower layers alike.

35. WEATHERING, HOED CROPS AND FALLOWING.

But, though a wise alternation of plants with different habits of growth be employed, the final result will be an exhaustion of the available plant food. The next consideration therefore, will be how to change the insoluble or unavailable into an available or soluble state. This result may be achieved by following, as well as we may, nature's method, which is to allow the atmospheric agencies to act upon the rock particles, or in other words to *weather* them. Weathering, acting upon the rocks, changed them to soils; weathering, acting upon the soil, made its constituents more soluble; and weathering ought to belong to every rational system of farming.

Fallowing aims, especially, to expose, by plowing, the different portions of the soil to the action of the air; and, secondarily, to supply the soil with organic matter; but it is, essentially, a weathering of the soil particles. Fallowing, however, is not always the best method for setting free the plant food of the soil, when we recall that the land while fallowing produces no crop. A more profitable fallow, with this in mind, is a *hoed* crop. The repeated hoeing given to a crop of corn or roots or potatoes serves to stir the soil and expose the lower lying particles to the action of the air. As a general principle it may be said that a hoed crop should belong to every system of rotation, and that fallowing which is its equivalent in results, should be practised at longer intervals.

36. HOW TO ADD NITROGEN TO SOILS.

The application of these principles will keep a supply of available plant food in the soil as long as insoluble material lasts; and in Utah soils one element only is likely to become deficient within a reasonable time. The element nitrogen, which is contained by soils in smaller quantity than any other constituent, is used by plants in greater quantities than any other plant food taken from the soil, with the exception of water; consequently, the supply, even in fertile soils, is likely to be soon exhausted. Inside of the Great Basin, many soils have already become deficient in this element, and a few never did contain enough of it. Outside of the Basin, and on its rim, many virgin soils can not produce one good crop, though watered abundantly, because of the lack of this element; and, often, ignorance of the principles of agriculture has left otherwise fertile lands unused for many years, while lands poorer in most ways, but containing more nitrogen, have been cultivated. Before proceeding to a discussion of the methods whereby nitrogen can be added to the soil, it may be well to say that some Utah soils, especially those of great fertility, are abundantly supplied with nitrogen, and any addition of this element would not be beneficial. A farm known to the writer produces heavy yields for six or seven years in succession, when it is usually given a summer's fallow. The next year the crop, say wheat, runs to stalks and leaves, standing sometimes man high, but poor in grain; showing an excess of nitrogenous food which has been set free by the fallow. It must be emphasized that such cases are not very numerous.

The element nitrogen is very abundant in nature, it forms four-fifths of the atmosphere. Plants can not take it from the atmosphere, directly; nor can they use it in the free state; to be of use as a plant food, it must be in the form of a nitrate. Nature has, however, made a special provision in this matter for the benefit of the farmer. All plants which belong to the *leguminosæ*, or which carry their seeds in pods, have the power of taking nitrogen from the air by indirect means. They can do this through the action of minute plants, microorganisms, that settle and grow upon the roots of podbearing plants, and which have the power of taking free nitrogen from the air and changing it into a form fit for the use of plants. If a root of clover, or pea or lucern, etc., be taken from the soil and examined, numerous small swellings, and spherical bodies, will we seen upon it and suspended from it by threads. These swellings or *tubercles* are the homes of the nitrogen gatherers and indicate a healthy state of the plant. As far as known today, only the leguminous plants will support these minute organisms upon their roots. A leguminous crop grown upon a piece of land will enrich it very much, even if the crop be taken away, for the roots will remain and they will be heavily charged with nitrogen, which will be of value to the crop of the next season. If a crop of clover, for instance, be plowed under, the results will be more favorable, for then all the nitrogen in the leaves and the stalks can be utilized by the succeeding crops.

To replace the nitrogen taken away by crops, or to increase the amount already present, a leguminous or podbearing crop should be made a part of every rotation. The crops that may be used are many: peas, beans, the clovers, including lucern, vetches, etc.

37. GREEN MANURING.

A word should be said here on the subject of green manuring. If clover, to illustrate, is grown to replenish the soil stock of nitrogen, it is well to plow under the last crop of the season. This is not only to supply the soil with more nitrogen, but to obtain the beneficial action of decaying vegetable matter upon the soil. The green plant, in decomposing, generates many acid substances that doubtlessly act upon the soil grains with their partial solution; and, after fermentation is completed, the soil is charged with organic matter that serves to retain the moisture, which is an important function in the arid Utah climate. A light soil will not, of course, receive so much benefit from such treatment as a heavy clay soil.

38. ROTATION OF CROPS.

With the principles here outlined, every agriculturist can construct for himself a rotation that will maintain the fertility of his land indefinitely: Plants with different habits of growth to exhaust the soil uniformly; a hoed crop to weather the soil and to set free plant food, and a leguminous crop to supply the soil with nitrogen. As an example of a simple, four-year rotation, we may take the famous Norfolk system: 1st, Wheat; 2d, Clover or some other leguminous plant; 3d, Barley; 4th, Turnips, or some other hoed crop. The very successful rotation of New York State is as follows: 1st, Barley or Wheat; 2d, Clover or some other leguminous crop; 3d, Corn, Potatoes or Roots; 4th, Oats. Any other rotation, of four years' duration or longer, may be constructed, according to individual needs; but a hoed crop and a leguminous crop should never fail to make their appearance in it.

Many will urge, upon reading this, that rotation is not possible in Utah because of the markets. While this bulletin can not include a discussion of this subject, yet it may be said that the concensus of the best agricultural thought in Utah today, is that there is room for improvement in the farm practices of the State; that Utah farming should be more diversified; and that more of its products should be fed at home, so that the finished and more profitable product could be sold. Moreover, it requires no prophetic insight to predict that before many years roll away, there will come a time when the agriculturists of this State will be compelled to follow some rational system of rotation if they wish to maintain the fertility of their soils. In that day the methods must be varied, so as to meet the markets with the rotation of the crops.

39. MANURING.

The manuring of cropped fields is a subject of great importance, but it has been so fully discussed in other popular publications as to require but a passing treatment here. Manuring really means returning to the soil as much as possible of the material taken from it. In an ideal system of farm practice this would be done by feeding all the products of the soil to animals and returning all the manure obtained. In such a system the fertility of the soils would be kept up for a very long time. Stable manure should not be allowed to go to waste or given away to anyone who will haul it off, as is often done here, but should be carefully kept and spread upon the fields; it is gold and silver to the tiller of the soil. The same can be said of straw and other waste products, the ashes of which should at any rate be scattered upon the cultivated land. Along with manuring should always go a rational system of crop rotation.

40. COMMERCIAL FERTILIZERS.

The question of artificial fertilizers is different. Many people seem to think that if they buy a few hundred pounds of commercial fertilizers, recommended only by the seller, and spread them upon their fields, they must of necessity obtain glorious results, that cannot possibly be obtained in a different way. This, for the people of Utah, is a mistaken idea. Utah soils are rich in all plant foods, which await only proper treatment to be made available for plants. Money spent for commercial fertilizers to be applied upon the soils of this state can not yield profitable returns. The same money applied to bettering the farm machinery or for labor to carry on proper soil tillage would have better and more lasting results. The time has not yet come for the fertilization of Utah soils.*

*This does not refer to gypsum, or lime, or similar substances that are used to improve alkali lands, or sour soils, or heavy lands, etc.

The experience of older countries teaches that the most fertile soils may be rendered unproductive by improper tillage. Modern science, applied to agriculture, teaches that by following nature's suggestions, even infertile soils may be raised to passable productivity. We, of Utah, should profit by the experience of the past and the knowledge of the present, and not hesitate to treat our soils so that they will not only yield *us* well, but also be in good condition for the following generations, our sons and daughters. Progress means success.